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6 PARKA II-A BOTTOM LOSS MEASUREMENTS [U]

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by

10 S. R. Santaniello and S. R. van der Veen

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INTRODUCTION

Bottom Loss Measurements were conducted during the PARKA II-A experiment in the vicinity occupied by R/V FLIP for the main propagation loss measurements. The objective was to obtain low frequency (100-1000 Hz) bottom loss values for use in models for predicting propagation loss. The location is approximately 300 miles north of the Hawaiian Islands. Data was obtained as a function of grazing angle and frequency. A single hydrophone was suspended at a depth of 11000 ft below the USNS SANDS while the R/V CONRAD detonated explosives at depths of 500 and 11000 ft as range was varied. Because of the location for the measurements these results are compared to MGS AREA-V GROUP-V low frequency results.

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Sponsoring Activities: ONR and NAVSHIPS
ONR Project Manager: J.B. Hersey, Code OS-102
NAVSHIPS Program Manager: J. Reeves, Code OOVIL
NUSL Principle Investigators: R.W. Hasse and S.R. Santaniello
Titles: PARKA II-A Bottom Loss
Forward Scattering Studies for Sonar Design and Performance Prediction

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DISCUSSION

Operational Procedures

The PARKA II-A bottom loss measurements were conducted during two periods, 15-25 September and 1-8 November 1969. The R/V CONRAD was employed as the source ship and the USNS SANDS as the receiving ship. During the first period, SANDS held station as CONRAD started at a range of 300 yards from SANDS and opened to 80000 yards detonating three-pound explosives at a depth of 500 feet. The detonation rate was such that bottom reflected signals occurred within two degree intervals for grazing angles greater than 30 degrees and within one degree intervals for grazing angles below 30 degrees. CONRAD opened and closed range along three tracks 0, 60, and 240 degrees true from SANDS (Figure 1).

For the second test period three-pound explosives were detonated at 11000 feet. This depth was used to provide a suitable time separation between the various acoustic paths from source to receiver, permitting loss comparisons between the directly propagated and the bottom reflected acoustic pulses.

The operations for the two periods were similar. However, for the second period it was far more difficult to position SANDS because a reaction buoy used for the first period was no longer available for reference. In addition, the detonation time of the explosives as measured from the times they were overboarded varied from 14 to 21 minutes requiring a wide data acquisition time aperture. Also a high dud rate was experienced for the deep explosives. Since the exercise required a uniform detonation rate with the ship underway, the high dud rate was unacceptable. The operations were therefore modified, with CONRAD taking stations at fixed ranges and dropping five explosives, one every five minutes. Thus, data were acquired at more widely spaced intervals. Only one track, 0 degrees true from SANDS, was completed because unfavorable weather curtailed operations. Because of the small amount of data acquired during the second period there is limited statistical significance to the results using the deep explosives.

Data Acquisition and Pre-Processing

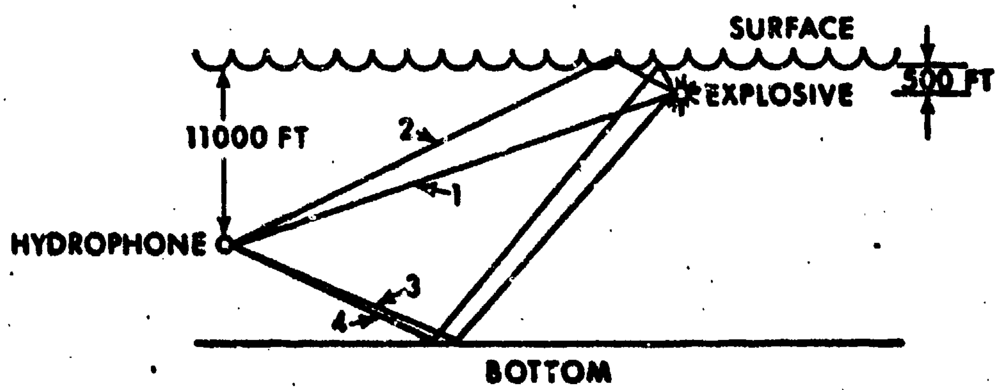
For the shallow explosives (500 ft) the instantaneous signals from the hydrophone amplifiers were filtered through 1/3 octave filters centered at 100, 180, 400 and 800 Hz, rectified, averaged and digitally recorded. In addition, the instantaneous signals were recorded broadband on an FM tape recorder at 15 ips to obtain data to 5000 Hz. Signals were also pre-filtered through a 3500 ± 500 Hz filter and

recorded on another analog channel.

Processing for the deep explosives (11000 ft) was the same as for the shallow explosives. In addition, the instantaneous signal from the hydrophone amplifiers was pre-filtered through a 200 Hz low-pass filter and amplified for processing through the 100 Hz third octave filter-detectors, prior to digitizing. The output of the low-pass filter was also analog recorded. This pre-filtering was performed to correct for the spectral energy distribution of the deep explosives.

Data Processing

The sequence of acoustic signals (pulses) arriving at an 11000 ft hydrophone for an explosive detonated at 500 ft, in 18000 ft of water, is (1) direct, (2) surface reflected, (3) bottom reflected and (4) surface-bottom reflected.



The maximum time separation between the shock wave of the direct arrival and the shock wave of the surface reflected arrival will occur when the explosive is directly above the hydrophone, and will be approximately 200 milliseconds. Contained within this time interval is the bubble pulse of the direct arrival. This time separation decreases with range and the direct bubble pulse and surface reflected shock wave eventually overlap in time. Because of the small time separation between the first two arrivals, they are combined into one signal aperture and identified as a single arrival. The first two signal apertures are defined as follows:

SIGNAL APERTURE	PATH COMBINATION
A	Direct and Surface
B	Bottom and Surface-Bottom

The signal apertures were identified and isolated for acquisition using a threshold criterion based on a noise level measurement made prior to the arrival.

The received energy levels were determined by squaring and integrating the detector-averaged signals in each signal aperture. For deep explosives where the various arrivals can be resolved in time a simple comparison between direct and bottom reflected signals resulting from a given explosive is correct. For the shallow explosives the difference in energy between apertures "A" and "B", after appropriate correction for spreading loss, in essence can be attributed to bottom loss. However, where the direct and surface reflected signals of aperture "A" arrive close together in time and cannot be separated, interference can occur between these signals causing the source to act as though it were directional. This is discussed in detail in the PARKA I report. In such instances it is possible for the apertures "A" and "B" to be associated with somewhat different source levels.

To determine if such interferences would influence these bottom loss results, the level of the signal occurring in aperture "A" was plotted as a function of separation between source and receiving ship. After correcting for range the variation in level was found to be random rather than deterministic. This analysis showed that for these results there should be no effect on the general shape of the bottom loss curves as a function of angle due to possible variations in source level except for a minor influence on the scatter of the results.

The results presented were therefore obtained using a single source level determined in the following manner. The energy contained in signal aperture "A" was measured for each frequency band and for the receptions along each track. This information, corrected for spreading losses, was compiled into a histogram of apparent source levels. The "most probable" value at each frequency was selected and assigned as a range-independent, omnidirectional, source spectrum level. The energy contained in signal aperature "B" was then measured, corrected for spreading loss, subtracted from the "most probable" source spectrum level and converted to db-space for the bottom loss value.

The difference in time of arrival between signals of apertures "A" and "B" was used to determine the path length for each arrival and the grazing angle for the bottom reflected signals. All computations were based on a ray tracing program which took into account (1) the velocity profile of the water column during data acquisition, (2) the average

water depth over the track and (3) the depths of the source and receiver.

Results

For the shallow explosives data were obtained for grazing angles from 15 to 85 degrees over the first 20000 yards along each track. Bottom loss values for all tracks were combined according to frequency and grazing angle. Figure 2 shows composite plots of the data for the four frequencies. The loss values contained in each 2.5 degree angle bin from 15 to 85 degrees, for each frequency, were averaged. Because of the spread in the data a second-order least square polynomial fit was applied to the 2.5 degree angle bin averages. Bottom loss values range from 0 to 12 db for the 100 and 180 Hz bands, and from 3 to 12 db for the 400 and 800 Hz bands.

The 100 Hz band values exhibit the greatest spread in values which is attributed in part to the processing bandwidth of the third-octave filter. The time interval between the shock and bubble pulses, coupled with the Lloyd mirror effects, produce a series of impulses with arrival times less than the time constant of the 100 Hz filter; these arrival times vary with range.

The quadratic curves from Figure 2 are compared in Figure 3. The curves for 100 and 180 Hz are very similar (within 1 db); the gross magnitude of loss is approximately 5 ± 1 db for the angles 15 to 85 degrees. The 400 and 800 Hz curves are also very similar, with gross magnitude of loss approximately 7 ± 2 db. Bottom loss as represented by the smooth curves show no obvious angle dependance between 15 to 85 degrees and appear to be only slightly dependent of frequency; showing an approximate 2 db difference in mean value between 100 and 800 Hz.

Ocean Bottom Structure

The geologic structure of the ocean bottom was studied using bathymetric records, sediment cores and oblique angle acoustic reflections. Figure 4 presents a 3.5 kHz bathymetric record taken aboard CONRAD. This record was supplied by J. Ewing and C. Windisch of Lamont-Doherty Geophysical Observatory where analysis of a number of profiler records indicated the following:

> There is an acoustically transparent layer of mud overlaying a strongly reflecting surface. Assuming the transparent layer has a sound velocity close to that of sea water, the thickness over the region varies from 48 to 72 ft. A few weak reflectors have been observed within the transparent layer. One of these seems relatively extensive and appears at about

midway; 24-36 ft. Coring experience indicates these reflectors to be thin layers of volcanic ash. From the JOIDES drilling the strong reflector would appear to be a layer of chert. However, this reflector is very weak on the lower frequency seismic data recordings suggesting it is probably quite thin. Seismic profiles taken in the vicinity of the acoustic stations indicates a transparent sediment (at seismic frequencies) overlying oceanic basement (4.5-5.5 km/sec). Assuming a sound velocity of 1.8 km/sec in the transparent sediment, the thickness ranges from approximately 170 to 320 ft.

A first order approximation of the dominent sub-bottom layers affecting the oblique angle reflections could also be obtained using the reflections for the 11000 ft explosives. In the upper portion of Figure 5 is an oscillograph trace of the instantaneous signal for one of the reflections. On the left is the direct arrival showing the shock and bubble pulses; on the right is the associated bottom reflected acoustic pulse for a six-degree grazing angle. The lower portion of Figure 5 is the envelope of the bottom reflected signal processed through an optimumly adjusted detector-averager. This process was to first full wave rectify the broad band instantaneous direct arrival and then pass this signal through a low pass filter that was adjusted to form an envelope of the direct arrival such that it approached a sine-wave shaped impulse. The bottom reflected arrivals for the 11000 ft explosives were then passed through the processor to determine the time difference between arrivals as they appeared within the total bottom reflection. Since there is no pre-filtering to this process, the results are related to the peak of the spectrum for the 11000 ft explosives (350-400 Hz) and the time resolution is related to the pulse length (4-5 msec).

The detector-averaged envelope shown in Figure 5 illustrates the result of the process showing two distinct reflections contained within the total bottom reflection; the weaker off the water-sediment interface and the stronger off the oceanic basement. The difference in arrival is approximately 7.5 milliseconds. A first-order approximation of the depth of the oceanic basement can be determined using a form of Bragg's diffraction relationship.

$$d = \frac{c\,\tau}{2 \sin \theta}$$

Assuming a sediment sound velocity (c) of 5000 ft/sec and setting $\tau = 7.5$ msec and $\theta = 6^{\circ}$, the oceanic basement is estimated to be 180 ft below the water-sediment interface; this falls within the range of 170 to 320 ft. This type of analysis was performed on data for 22 deep

explosives covering the grazing angles from 6 to 30 degrees. The results presented in Table I, estimated three dominant sub-bottom layers at depths ranging from 25-45 ft, 70-110 ft, and 121-212 ft below the interface and in reasonable agreement with the values determined from the bathymetric analysis.

TABLE I

SUBBOTTOM LAYER DEPTH ESTIMATES

Shot No.	Angle Est.	L_1 depth ft	L_2 depth ft	L_3 depth ft
1	30.0		78	156
2	"			141
3	"		94	125
8	27.5		91	142
10	"			121
12	25.0			185
13	"		110	159
14	"		110	170
15	"			178
17	22.5			163
18	"			176
20	"			212
22	20.0			137
27	18.0	25	70	
30	"	35		
31	"	34		181
35	"	45		170
42	14.0		78	
46	12.0		105	
66	8.0			157
67	6.0			180

Three sediment cores were obtained along the three tracks and were analyzed by D.R. Horn of Lamont-Doherty Geophysical Observatory. The sediment samples were composed of uniform red clay over the 30 ft length of the cores; characterized by a low sound velocity. Sound velocities of approximately 4900 ft were estimated by geological analysis. With a sound velocity in the upper sediment layer lower than that of the overlying water, theory for the simple two-layer model predicts an angle of intromission related to the ratio of the impedances at the water-sediment interface. At the angle of intromission there is an absence of reflected energy for all frequencies.

With the shallow explosives it was not possible to indicate an angle of intromission, because the angle coverage was limited to grazing angle greater than 15 degrees. However, intromission is indicated by the dashed curve of Figure 3 which resulted from processing the twenty-two 11000 ft explosives. Even though there is not a sufficient amount of data to be definitive, the broad band processing (10-1000 Hz) shows a large amount of energy loss ($>$ 10 db) in the region of 8 to 10 degrees grazing.

Theory further predicts a 180 degree phase reversal of the reflected signal with respect to the incident signal, for grazing angles less than the angle of intromission. Figure 5 supports both the theory and the geological determination of a low sound velocity for the upper sediment. The initial instantaneous signal reflected off the water-sediment interface is phase inverted with respect to the instantaneous direct arrival, for the reflection angle of six degrees grazing. Acoustic signals with wavelengths equivalent to those employed in these measurements, and incident to this ocean bottom at grazing angles between 8 to 10 degrees, should be highly refracted and passed into the ocean bottom.

Comparison to MGS Results

The Marine Geophysical Survey Program 65-67 acquired geophysical information in a large area around and north of the Hawaiian Islands; Area-V. Results of the bottom loss measurements made over this extensive area are reported in reference (1). Figure 6 was reproduced from reference (1) to show the PARKA II-A bottom loss site in MGS Area-V and its proximity to the nearest MGS station; station 60. The results for station 60, however, were combined with a set of other stations (6, 18, 20, 37, 44, 45, 48, 49, 50, 52, 53, 54, 66, 67 and 75) because of similar bottom characteristics and designated as acoustic province Group-V. The composite MGS bottom loss curves for Group-V is Figure 14 of reference (1) and is reproduced in Figure 7. Superimposed on the MGS chart is the PARKA II-A quadratic curve fit to the 400 Hz third-octave band results; Figure 2. Figure 8 is presented to illustrate the extent of the difference between the PARKA II-A 400 Hz results and the MGS 500 Hz results. It shows (1) the 400 Hz data with the 2.5° angle bin averages for the 500 ft explosives (solid line) covering the grazing angles from 15 to 85 degrees and (2) the results for processing the 11000 ft explosives through the 400 Hz third-octave filter (dashed line) to cover the angles below 15 degrees; illustrating intromission. It is obvious that the MGS 500 Hz bottom loss averaged results are outside the spread of the PARKA II-A 400 Hz bottom loss results.

The difference in results (6 to 10 db) is considered significant. Even though this difference can be attributed in part to the location and area coverage, it is not unexpected when considering the acquisition and processing procedures. A comparison of these procedures is outlined:

PARKA II-A (NUSL)	MGS (ALPINE)
GEOMETRY	
Two ships opening range. Two configurations; majority of data using 500 ft shots and 11000 ft HYD; small no. of 11000 ft shots and 11000 ft HYD	Two ships opening range. 800 ft shot (MK 61) and 1000 ft HYD
SOURCE LEVEL ESTIMATE	
For shallow shots, combined energy of signals arriving over direct and surface paths. Received levels corrected for spreading loss and total energy (based on threshold criterion) determined to form source energy histogram where most probable value used for processing. Deep shots uses comparative measure, no source level required.	Determined comparing peak amplitude between 1st and 2nd normal incident reflections corrected for spreading loss. Results compared to empirical curves for MK 61 shot.
PROCESSING	
For shallow shots, most probable source level energy containing surface reflection compared to total bottom reflected energy containing surface reflection. Total bottom reflected energy based on threshold criterion and bottom loss determined after spreading loss correction. Path length based on time difference of arrival of signal apertures at 11000 ft HYD which is	Peak pressure of bottom reflection determined, corrected for spreading loss and compared to source level; difference bottom loss. Path length for spreading correction. based on range between ships and incorporated into computer ray plotting program.

incorporated into ray tracing computer program using velocity profile acquired during measurements.

ANGLE ESTIMATE

Determined along with path length; based on ray tracing program. Bottom loss values averaged over 2.5° angle bins for shallow shots using approximately 6 shots/bir; averages fitted to 2nd order polynomial curve.

Determined using range between ships and computer ray plotting program. Results for approximately 100 shots averaged over 10° angle bin.

Fowler and Bednar, reference 2, have empirically shown that large differences can occur in bottom loss results depending on the processing procedures. The differences between the PARKA II-A and MGS bottom loss results are attributed primarily to the differences in processing where NUSL's results were based on total energy and ALPINE's results where based on peak energy.

SUMMARY

Measurements of bottom loss were made in the vicinity occupied by the R/V FLIP during the main PARKA II-A experiment. For explosives detonated at a depth of 500 ft the acoustic bottom reflections received on a 11000 ft hydrophone were processed through third-octave filters centered at 100, 180, 400 and 800 Hz. Quadratic curves fitted to the data indicated the loss to be moderate for frequencies between 100 and 800 Hz. The gross magnitude of loss for grazing angles from 15 to 85 degrees is in the order of 5 ± 2 db. Bottom loss as represented by these smooth curves shows no obvious angle dependance between 15 to 85 degrees and indicates a slight frequency dependance of 2 db over the frequency range. The major reflected energy is from the oceanic basement some 170-320 ft below the water-sediment interface. The depth of the basement was determined through bathymetric analysis and acoustic analysis of oblique reflected signals.

Sediment core analysis showed a low sound velocity sediment overlying the oceanic basement. The analysis of a small number of explosives detonated at a depth of 11000 ft indicated an angle of intromission in the region of 8 to 10 degrees grazing caused by the low

sound velocity sediment, resulting in significant angular dependance of bottom loss at the low grazing angles.

Because these measurements were conducted at a site within MGS AREA-V, comparison of results are made. The bottom loss for the MGS Area-V, Group-V 500 Hz results was found to be between 6 to 10 db greater on the average than the PARKA II-A 400 Hz results. Although the difference in location and area coverage is significant, the difference in results is primarily attributed to the processing of data based on peak energy (MGS) as opposed to total energy (PARKA).

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Senior Project Engineer

Steven van der Veen
S. R. VAN DER VEEN
Physicist

REFERENCES

1. Alpine Geophysical Confidential Report No. SP-96-V-1 (Area V(1)) of October 1966, W.T. McGuinness, E.T. Miller, J.L. Simon and C. Lobel.

2. Tracor Confidential Report No. 68-1328-C of 14 March 1969, "Peak and Total Energy Bottom Loss Analysis", by S.F. Fowler and J.B. Bednar.

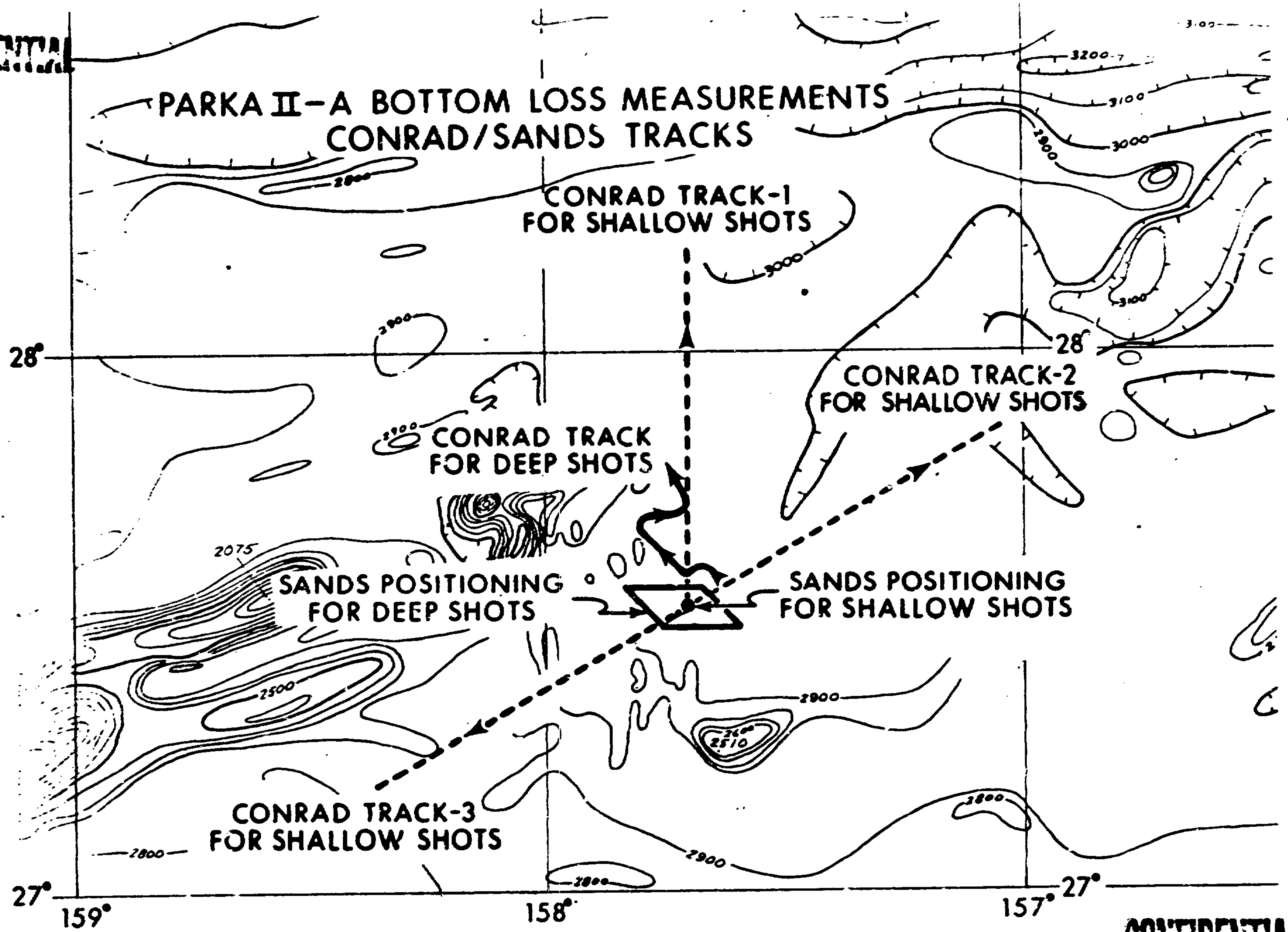

Figure 1 - Ships Tracks for PARKA II-A Bottom Loss Measurements

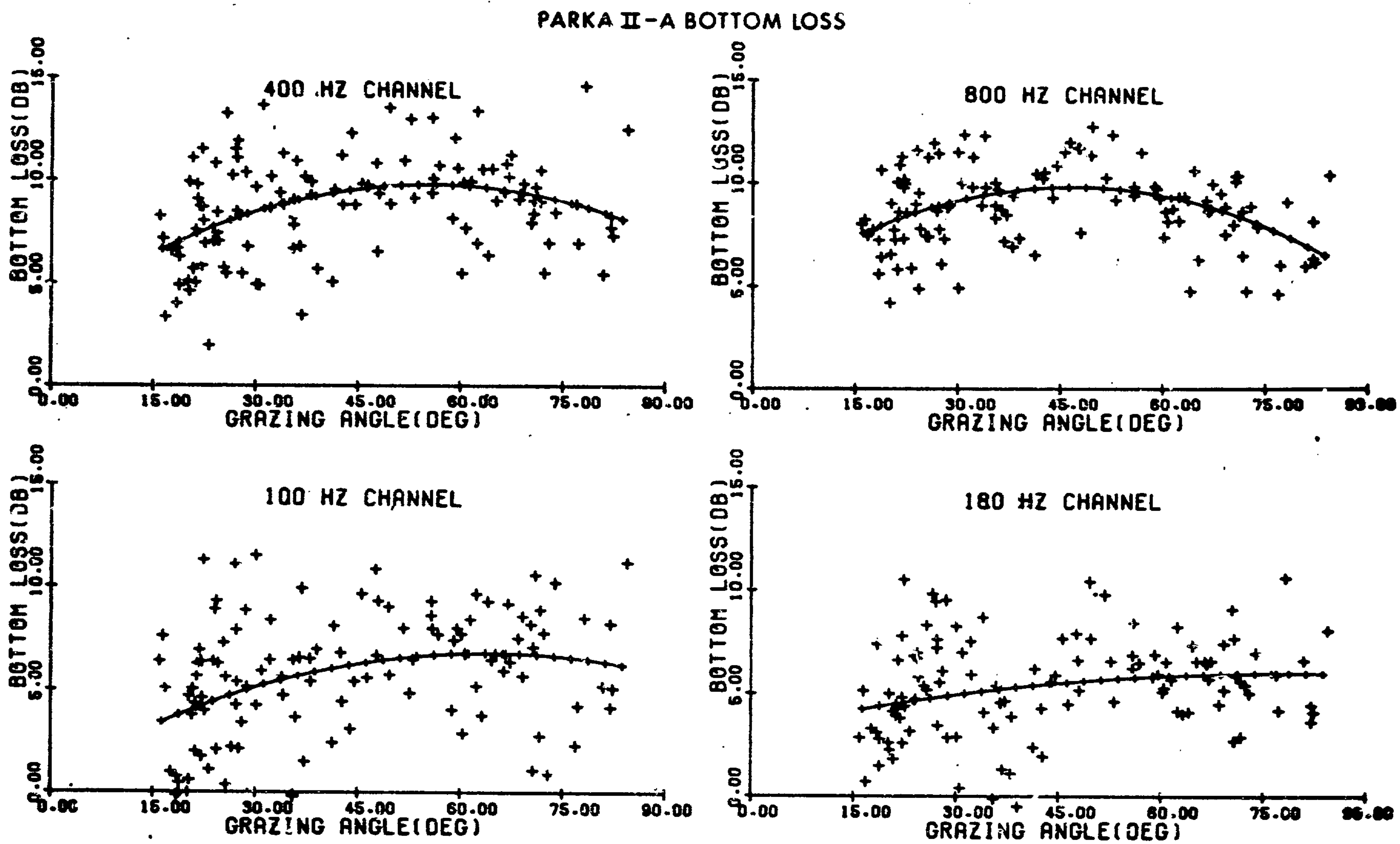

Figure 2 - Bottom Loss Values for 500 ft Explosives with Curves for Second-Order Square Polynomial Fit to 2.5° Angle Bin Averages

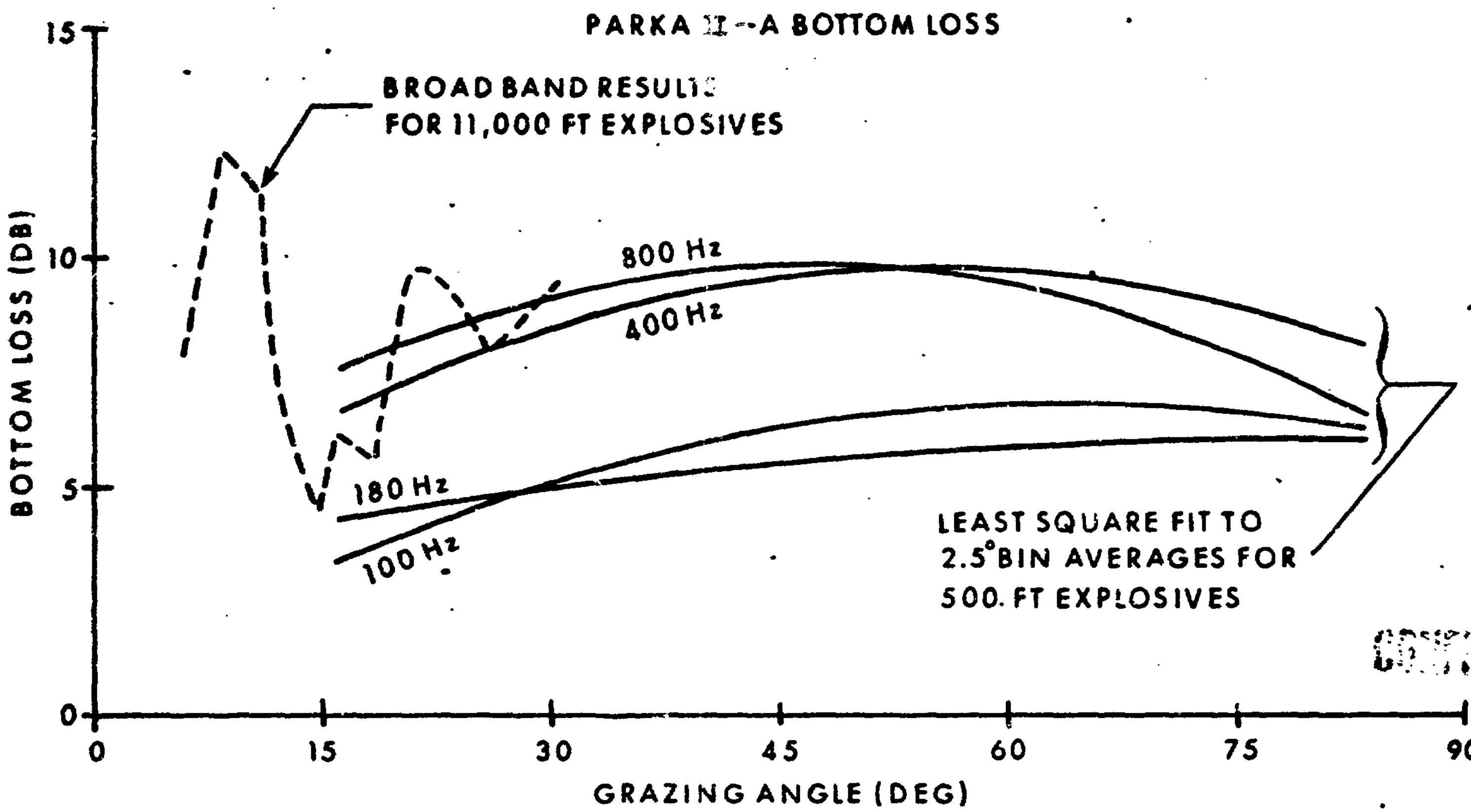

Figure 3 - Bottom Loss Curves for 500 ft Explosives and Broad Band Results for 11,000 ft Explosives

PARKA II-A BOTTOM LOSS

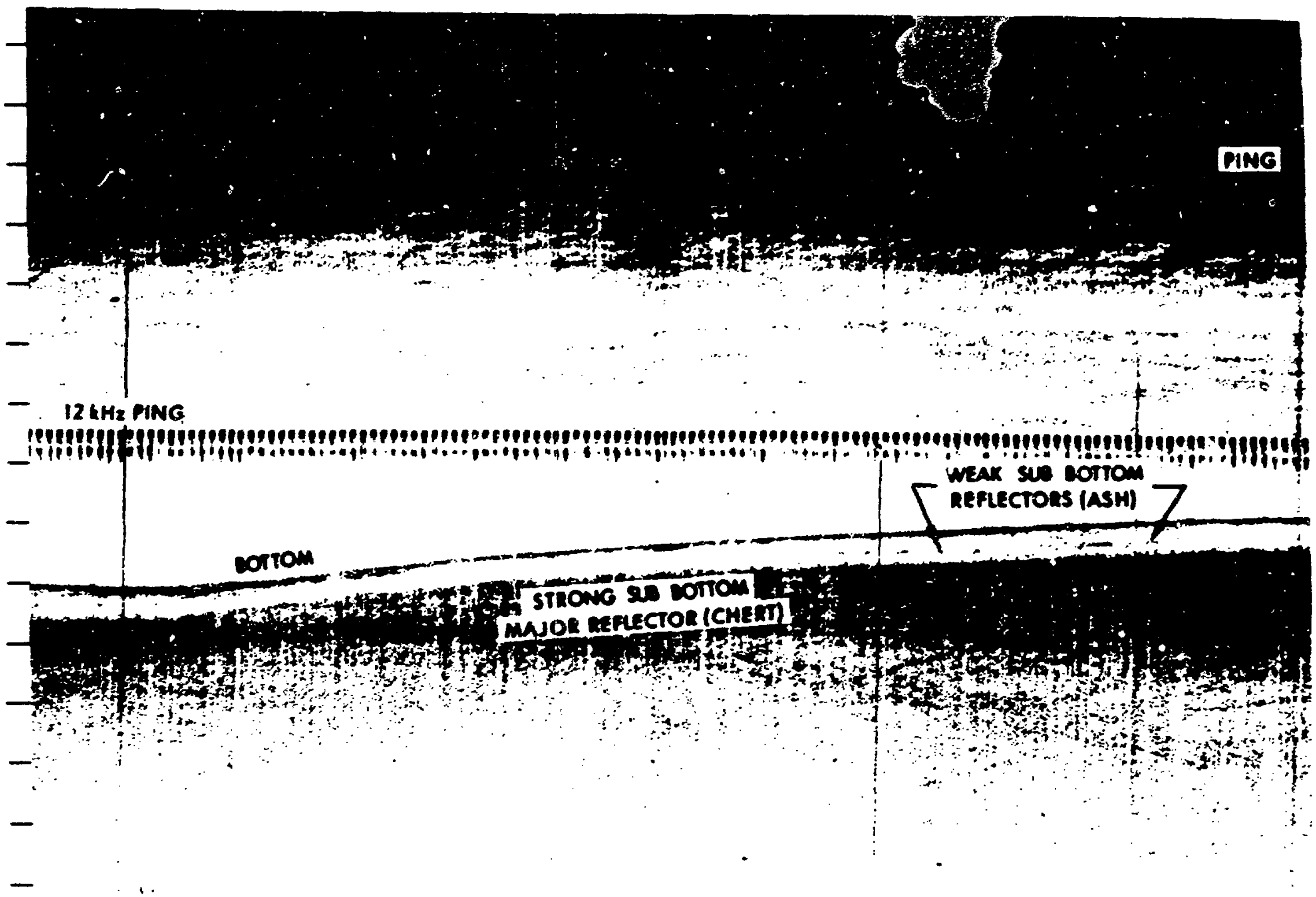

Figure 4 - Bathymetric Record (3.5 kHz) Acquired by R/V CONRAD

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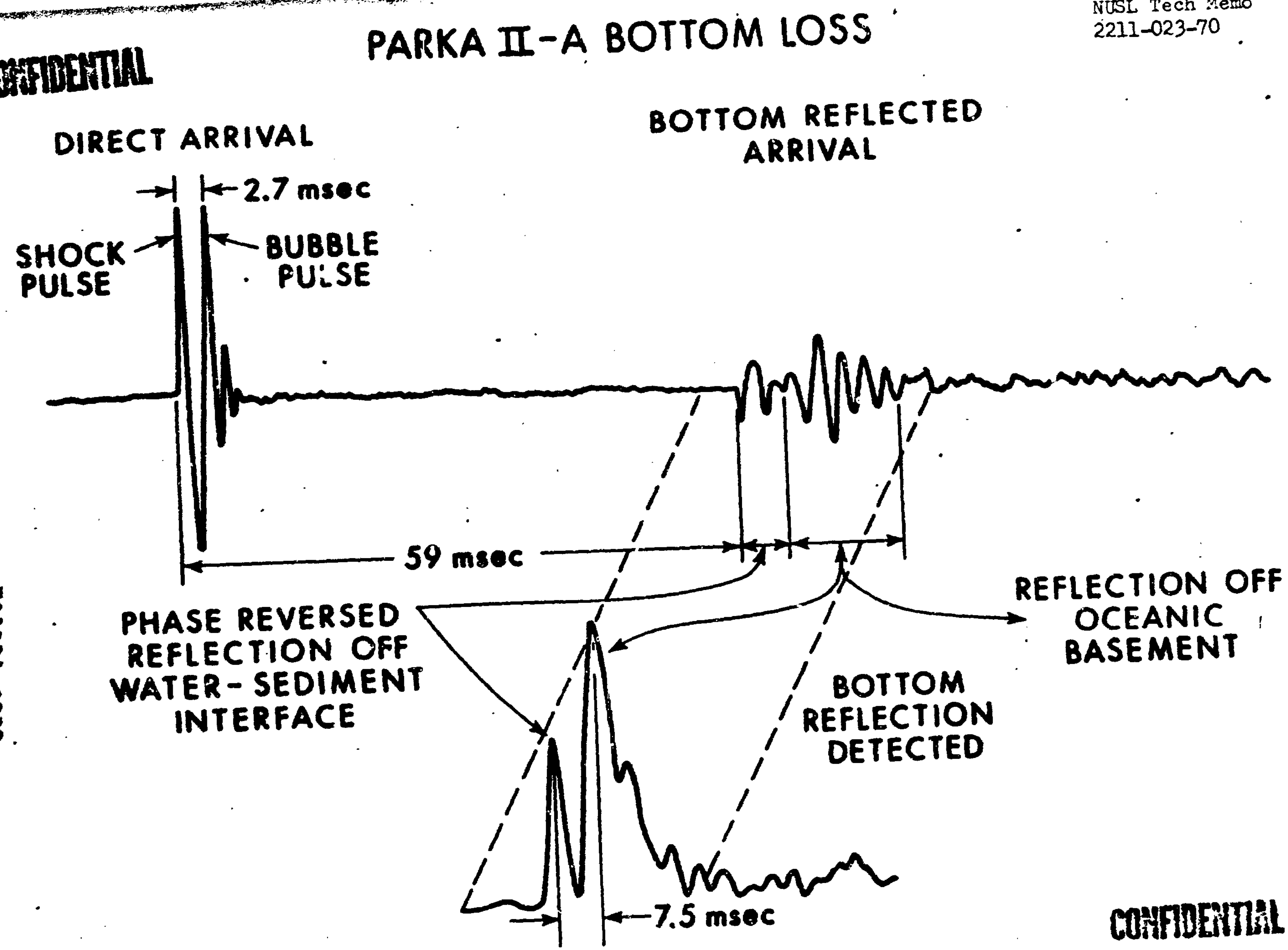

Figure 5 - Illustration of (1) Phase Reversal for Six Degree Grazing Angle Bottom Reflection From Low Sound Velocity Sediment and (2) Oceanic Basement Reflection

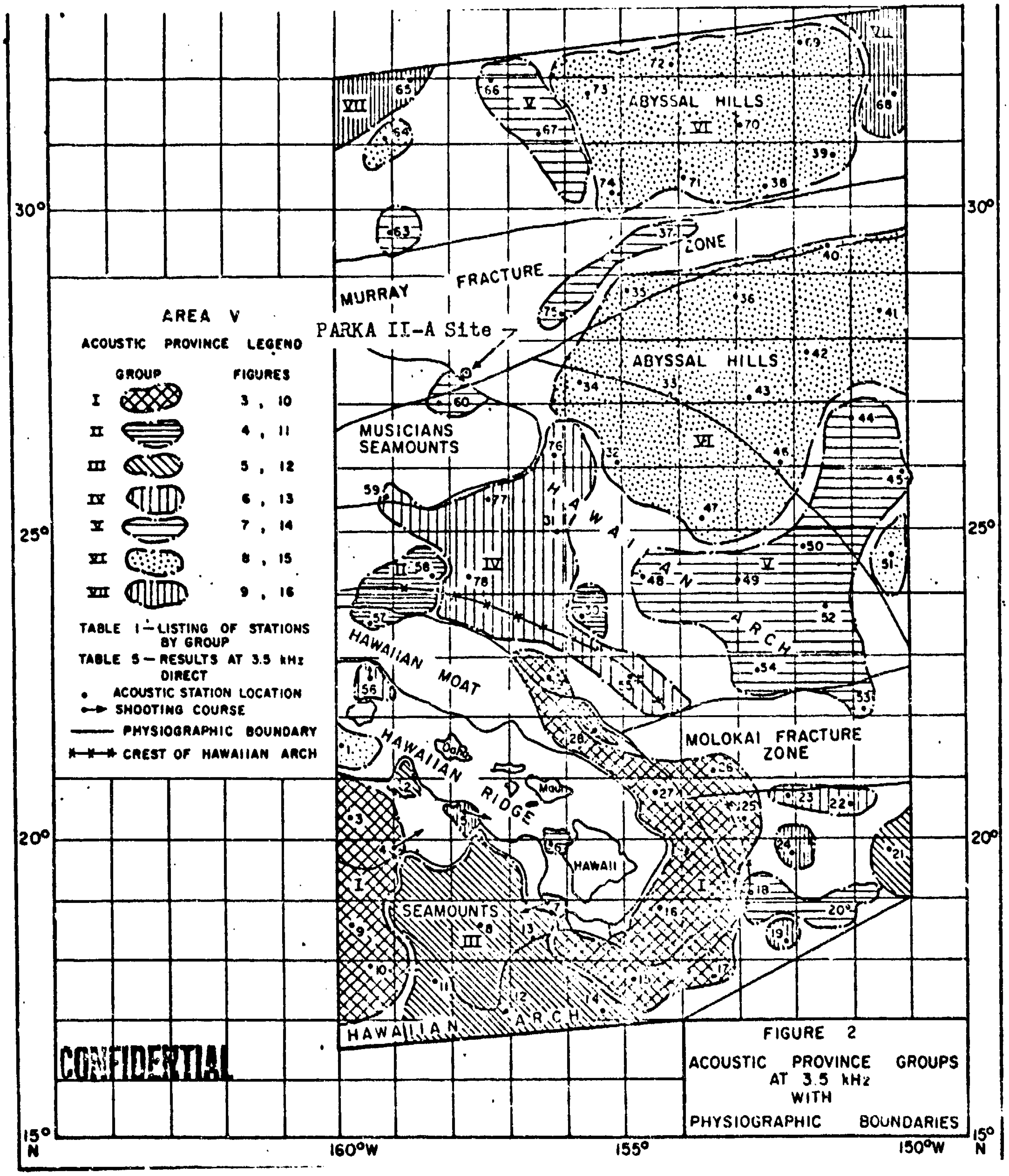

Figure 6 - (Reproduced from Alpine Confidential Report No. SP-96-V-I; Area-V, Volume-1, Figure-2) PARKA II-A Bottom Loss Measurement Site in Comparison with MGS Area-V Group-V Bottom Loss Measurement Sites

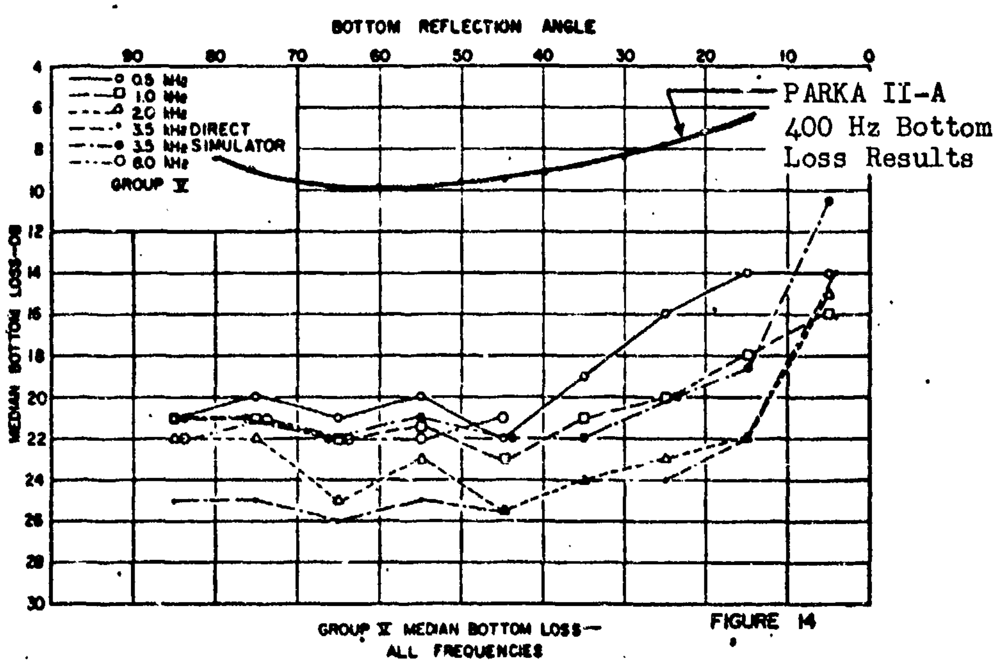

Figure 7 - (Reproduced from Alpine Confidential Report No. Sp-96-V-I; Area-V, Volume-1, Figure 14) Comparison of PARKA II-A 400 HZ Bottom Loss Results with MGS Area-V Group-V Bottom Loss Results

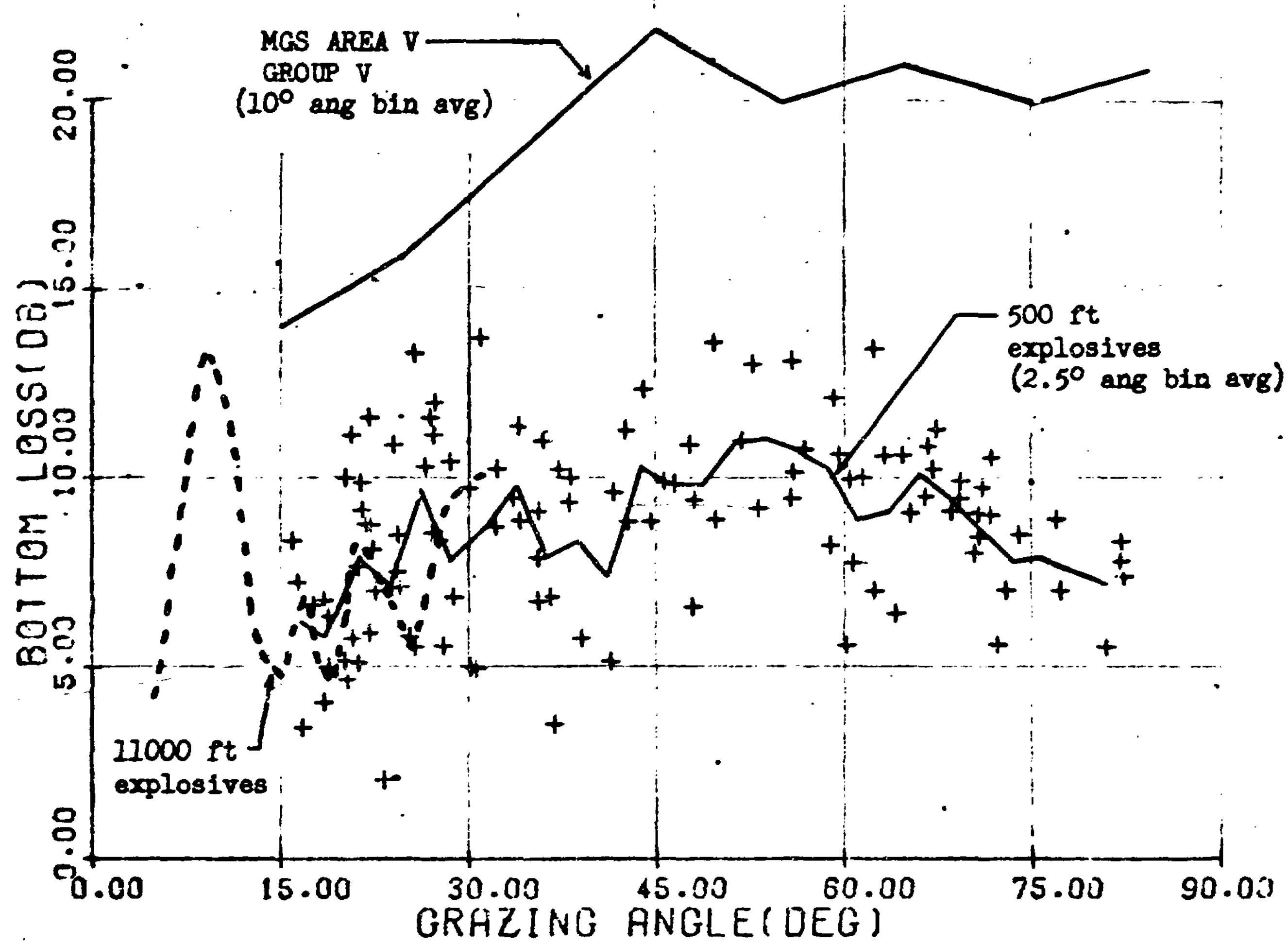

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Figure 8 - Comparison of MGS Area-V, Group-V 500 Hz Bottom Loss Results with Spread of PARKA II-A 400 Hz Bottom Loss Results

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From: Chief of Naval Research
To: Commander, Naval Meteorology and Oceanography Command
1020 Balch Boulevard
Stennis Space Center MS 39529-5005

Subj: DECLASSIFICATION OF PARKA I AND PARKA II REPORTS

Ref: (a) CNMOC ltr 3140 Ser 5/110 of 12 Aug 97

Encl: (1) Listing of Known Classified PARKA Reports

1. In response to reference (a), the Chief of Naval Operations (N874) has reviewed a number of Pacific Acoustic Research Kaneohe-Alaska (PARKA) Experiment documents and has determined that all PARKA I and PARKA II reports may be declassified and marked as follows:

Classification changed to UNCLASSIFIED by authority of Chief of Naval Research letter Ser 93/160, 10 Mar 99.

DISTRIBUTION STATEMENT A: Approved for public release. Distribution is unlimited.

2. Enclosure (1) is a listing of known classified PARKA reports. The marking on those documents should be changed as noted in paragraph 1 above. When other PARKA I and PARKA II reports are identified, their markings should be changed and a copy of the title page and a notation of how many pages the document contained should be provided to Chief of Naval Research (ONR 93), 800 N. Quincy Street, Arlington, VA 22217-5660. This will enable me to maintain a master list of downgraded PARKA reports.

3. Questions may be directed to the undersigned on (703) 696-4619, DSN 426-4619.

Peggy Lambert

PEGGY LAMBERT
By direction

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PARKA II Acoustic Results, 16 December 1969, USL-PUB-6001, NUSC New London, 106 pages
(NUSC NL Accession # 006001)

PARKA II Interim Report, 18 December 1969, Contract N00014-69-C-0088, Bell Telephone Labs, 129 pages
(NRL SSC Accession # 85007061)

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